ISSN 1691-5402
ISBN 978-9984-44-070-5
Environment. Technology. Resources
Proceedings of the 8th International Scientific and Practical Conference. Volume 1

COMPACTING MECHANISMS OF COMMON REED PARTICLES

Edgars Repsa, Eriks Kronbergs, Mareks Smits
Institute of Mechanics, Faculty of Engineering, Latvia University of Agriculture
J. Cakstes bulv. 5, LV 3001, Jelgava, Latvia
Ph.: +371 63080674, fax: +371 63020762; e-mail: Edgars.Repsa@llu.lv,
Eriks.Kronbergs@llu.lv, Mareks.Smits@llu.lv

Abstract. *The paper present experimental investigation results of common reeds (Phragmites australis) particle compacting in closed die. Common reeds are important natural biomass resource in Latvia. Compacting of biomass is very complicated process for solid biofuel production and there are many factors influencing to this process. The quality parameters of compacted biomass are described by European countries standards for solid biofuel. Density is the most important quality parameter of biomass compacting. The paper present results of common reeds particles compacting mechanism in closed die. Maximum pressure 212 MPa had been achieved in compacting. For compacting process evaluation has been determined pressing energy and density of briquettes. The minimum of density 0.87 g cm^{-3} have briquettes with particle size 12 – 13 mm, but maximum density 1.03 – 1.04 g cm^{-3} two particle sizes < 0.5 mm and 32 – 33 mm briquettes. Maximum value of energy consumption for compacting (~172 kJ kg^{-1}) has been obtained for reed particle size 32 – 33 mm, minimum value (~53 kJ kg^{-1}) for particle size less than 0.5 mm.*

Keywords: *briquette density, common reeds, compacting.*

Introduction

European Union energy policy determines the aim to increase using of renewable energy resources providing independence from imported energy and reduction of fossil fuel use. Substitution of fossil feedstock for energy by biomass is important measure also for greenhouse gas (GHG) emission mitigation.

In the rural area of Latvia open water systems (rivers and lakes) and wetlands play an important role. Area of eutrophic lakes has become overgrown by emergent vegetation – mainly common reed. This lake terrestrialization process is natural and so we have another biomass resource – reeds biomass, which can be used like straw material for energy production and also as industrial raw material. Common reeds are important natural biomass resource, because there are more than 2000 lakes with shorelines overgrown by common reeds in Latvia. Naturally reed biomass is material of low bulk density (0.02 – 0.06 g cm^{-3}), therefore compacting of biomass is one of the important processes for effective handling, transport and storage of this biomass material for solid biofuel production.

European countries have standards (ŌNORM 7135, SS 18 71 20 and DIN 51731) [1, 2] concerned with wood pellet and briquette properties. Demand of mentioned biofuel density is > 1.0 g cm^{-3} in standards. For compacting process evaluation has been determined pressing energy consumption and density of briquettes. The aim of investigation is to find necessary particle size for compacting common reeds to density > 1.0 g cm^{-3}.

Materials and methods

The main task of this investigation was determination of compacting force – displacement characteristics for compacting of different size reed particles. Reed stalk material biomass with moisture content of 8.7% was chopped to different length and had been used for densification. Recommended moisture content is in the range of 8 – 15% for biomass materials to product high quality briquettes. At this moisture content, the briquettes are strong and free of cracks and the compacting process is preferential [3, 4]. The moisture content was determined using standard ASAE S358.2 DEC93, where oven drying of the samples was carried out at 103 ºC for 24 h [5].

Particle size of chopped common reeds was determinate from sieve analysis: < 0.5; 1 – 2; 3 – 4; 5 – 6; 7 – 8; 12 – 13; 22 – 23; 32 – 33 mm. Fine particles readily absorb moisture then large particles, and therefore, undergo a higher degree of conditioning [3]. An important indicator of particle size is necessary cutting energy. Specific cutting energy per mass unit is growing considerably from 2000 J kg^{-1} to 4000 J kg^{-1} when shredding size is changed from 20 to 10 mm [6]. Biomass compacting represents technology for the conversion of biomass into a solid biofuel in shape of briquettes and pellets. Studying the densification behavior of common reed particles through experiments should help to understand the densification mechanisms that could produce high quality compacted products and to design energy efficient compacting mechanisms.

Compaction experiments had been carried out in closed die with diameter 35 mm by means of hydraulic press equipment (Fig. 1). Maximum pressure 212 MPa had been achieved in compacting. The dosage of 35 grams of chopped common reeds particles was used for every briquette pressing.

Fig. 1. **Hydraulic press**

Common reed stalk material ultimate tensile strength is 330 ± 29 N mm^{-2} [6]. As common reeds are the strongest stalk material between other energy crops, they can be used as representative energy crop.

The briquettes with different density had been obtained as result of compacting experiments. For density calculation the weight of briquette was measured on electronic scales Sartorius GM 312 with division 0.01 g and size of briquettes was measured with sliding calipers (division 0.1 mm).

During compacting experiments were recorded pressure and piston displacement values. For force calculation was used equation:

$$F = \frac{p \pi d_1^2}{4}, \quad (1)$$

where p – pressure, Pa;
d_1 – hydraulic press piston diameter, m.

Compacting work was obtained from force – displacement curves of graphical integration. Total specific energy (kJ kg^{-1}) of common reed compacting is calculated by equation:

$$E = \frac{W}{m}, \quad (2)$$

where E – specific energy of compacting, kJ kg^{-1};
W – work of compacting, kJ;
m – mass of compacted reed, kg.

Results and discussion

During compacting experiments force – displacement characteristic was determined. The shapes of force – displacement characteristics of compacting of different size reed particles were similar – nonlinear curves with two quasilinear parts are shown in Fig. 2.

The maximum piston displacement required for initial common reed particles compression to 13 MPa. Material final pressing occur with more rapid increase of pressing pressure and at a small piston displacement, about 1 – 2 cm. This force – displacement characteristics are necessary for design of biomass compacting mechanisms. Using different hydraulic circuits can be realized required force – displacement characteristic of compacting. Innovative press mechanism in shape of rhomboid linkage with hydraulic drive (Patent LV 14201) is recommended for briquetting of stalk material biomass.

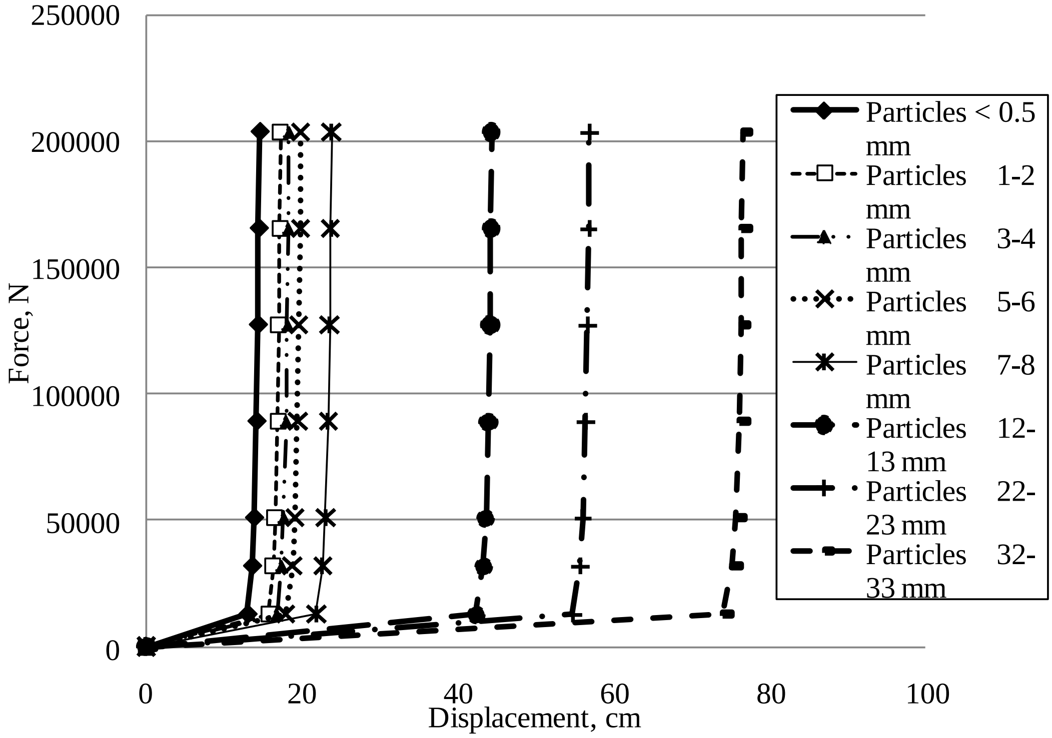

Fig. 2. **Force – displacement characteristics of compacting**

Density of reed briquettes obtained during compacting with pressure 212 MPa is shown in Table 1(D1 ÷ D9 – number of briquette). The density of briquettes was determined 0.87 – 1.04 g cm^{-3} with uncertainty ± 0.01 g cm^{-3}.

Table 1.

Common reed briquettes density

Particle size, mm	D1, g cm^{-3}	D2, g cm^{-3}	D3, g cm^{-3}	D4 g cm^{-3}	D5, g cm^{-3}	D6, g cm^{-3}	D7, g cm^{-3}	D8, g cm^{-3}	D9, g cm^{-3}	Average density, g cm^{-3}
< 0.5	1.014	1.025	1.026	1.034	1.046	1.052	1.058	1.022	1.032	1.034 ± 0.012
1 - 2	1.005	0.999	1.000	1.010	1.002	1.003	1.011	1.004	0.998	1.004 ± 0.011
3 - 4	0.964	0.960	0.985	0.982	0.974	0.982	0.990	0.985	0.994	0.980 ± 0.012
5 - 6	0.922	0.959	0.961	0.953	0.946	0.942	0.947	0.949	0.969	0.950 ± 0.009
7 - 8	0.894	0.879	0.886	0.921	0.893	0.903	0.920	0.923	0.933	0.906 ± 0.014
12 - 13	0.879	0.879	0.888	0.891	0.883	0.893	0.887	0.902	0.889	0.888 ± 0.008
22 - 23	1.013	0.980	0.970	0.954	0.957	0.958	0.977	0.971	0.964	0.972 ± 0.014
32 - 33	1.026	1.019	1.000	1.045	1.004	1.038	1.029	1.047	1.028	1.026 ± 0.016

The minimum of density 0.87 g cm^{-3} have briquettes with particle size 12 – 13 mm (Fig. 3), but maximum density 1.03 – 1.04 g cm^{-3} two particle sizes < 0.5 mm and 32 – 33 mm briquettes. Maximum density 1.026 g cm^{-3} of common reeds particle size 32 – 33 mm can be explained by particle orientation. This material size is nearly equal to die diameter and during filling particles start orientation for denser die filling.

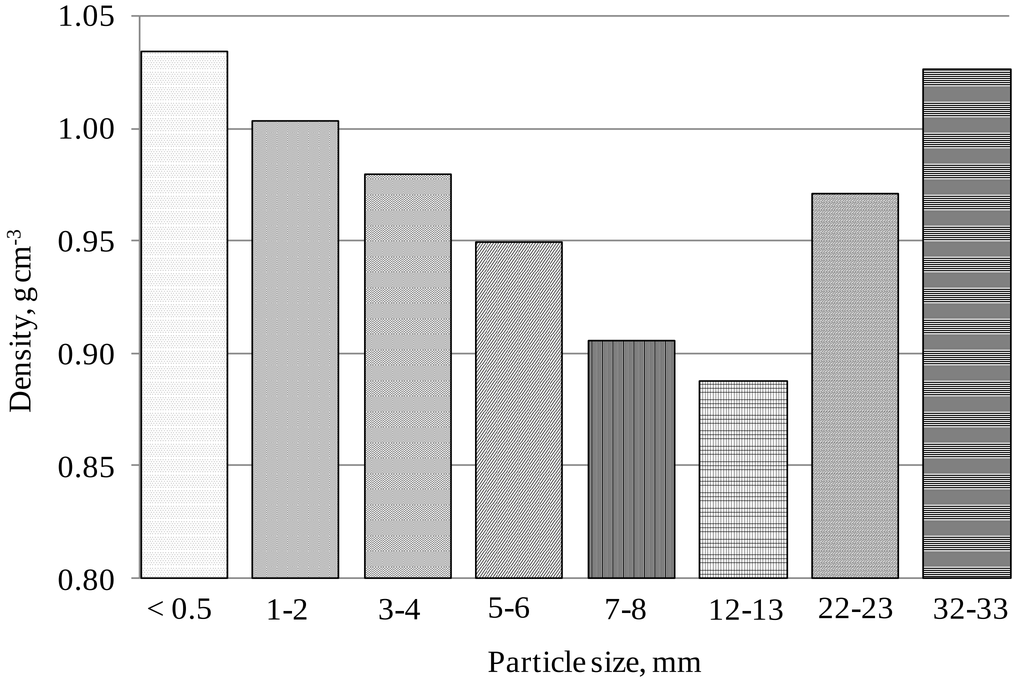

Fig. 3. **Common reed briquettes density**

Fig. 4 shows the pressing energy consumption for briquetting of chopped common reeds. Maximum value (~172 kJ kg^{-1}) has been obtained for reed particle size 32 – 33 mm, minimum value (~53 kJ kg^{-1}) for particle size less than 0.5 mm. For energy evaluation necessary compare pressing energy and cutting energy.

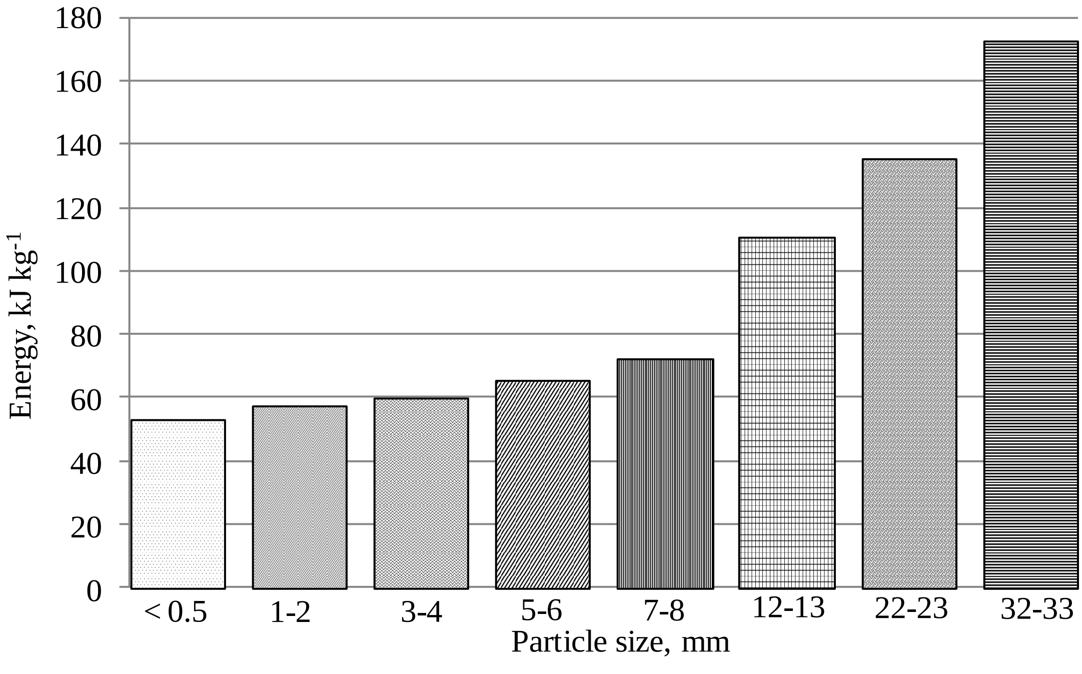

Fig. 4. **Compaction energy**

Specific cutting energy has been calculated for different particle of common reeds with density 615 kg m^{-3} and average specific cutting energy – 20 J m^{-2} by formula [6]:

$$E_c = \frac{E_{sc}}{l\rho}, \tag{3}$$

where E_c – specific energy of cutting, kJ kg^{-1};
E_{sc} – average specific cutting energy for square unit, kJ m^{-2};
l – particle size, m;
ρ – density, kg m^{-3}.

Maximum value (~62 kJ kg^{-1}) has been calculated for reed particle size less than 0.5 mm and minimum value (~1 kJ kg^{-1}) for particle size 32 – 33 mm. Energy economy we has 58 kJ kg^{-1} for pressing particles size less than 0.5 mm comparing with pressing reed particle size 32 – 33 mm then cutting energy is taken into account.

Conclusions

1. The minimum of density 0.87 g cm^{-3} have briquettes with particle size 12 – 13 mm, but maximum density 1.03 – 1.04 g cm^{-3} two particle sizes < 0.5 mm and 32 – 33 mm briquettes compacted with pressure 212 MPa in closed die.
2. The shape of force – displacement characteristics of compacting of different size reed particles were similar – nonlinear curves with two quasilinear parts.
3. Innovative press mechanism in shape of rhomboid linkage with hydraulic drive (Patent LV 14201) is recommended for briquetting of stalk material biomass.
4. Pressing energy consumption maximum value (~172 kJ kg^{-1}) has been stated for reed particle size 32 – 33 mm, but minimum value (~53 kJ kg^{-1}) for particle size less than 0.5 mm. The energy consumption difference is 119 kJ kg^{-1}.
5. Specific cutting energy maximum value (~62 kJ kg^{-1}) has been calculated for reed particle size less than 0.5 mm but minimum value (~1 kJ kg^{-1}) for particle size 32 - 33 mm. Energy economy we has 58 kJ kg^{-1} for pressing particles size less than 0.5 mm comparing with pressing reed particle size 32 – 33 mm then cutting energy is taken into account.

Acknowledgment

The authors are grateful for the financial support of this research from the European Structural Fund – Mobilization of human resources to renewable energy research project of Latvia University of Agriculture (project No. 2009/0225/1DP/1.1.1.2.0/09/APIA/VIAA/129).

References

1. Hahn B. Existing Guidelines and Quality Assurance for Fuel Pellets. PELLETS FOR EUROPE. Available at: http://www.pelletcentre.info/resources/1020.pdf, 10.01.2011.
2. Matúš M., Križan P. Influence of structural parameters in compacting process on quality of biomass pressings. Journal of applied mathematics. Volume 3, Number 3, 2010, p. 87 – 96.
3. Adapa, P., Tabil L and Schoenau G. Compaction characteristics of barley, canola, oat and wheat straw. BIOSYSTEMS ENGINEERING, Volume 104, Issue 3, 2009, p. 335-344.
4. Grover P., Mishra K. BIOMASS BRIQUETTING: TECHNOLOGY AND PRACTICES. Available at: http://www.fao.org/docrep/006/AD579E/ad579e00.pdf, 20.01.2011.
5. Moisture Measurement-Forages. Available at: http://m.doa.go.th/aeri/files/pht2008/lecture%20slides/mr%20viboon/grain%20drying/aeae- 1998/pdfs/section5/513.pdf, 15.12.2010.
6. Smits M., Kronbergs A., Kronbergs E. Herbaceous energy crop shredding size determination. In Proc. of 9th International Scientific Conference „ENGINEERING FOR RURAL DEVELOPMENT”, Jelgava, Latvia, 2010, pp. 275 – 279.

Anotācija. *Eiropas Savienības direktīva (2009/28/EK) nosaka, ka Latvijai līdz 2020. gadam no visiem izmantotajiem energoresursiem 40% jābūt atjaunojamajai enerģijai. Atjaunojamo energoresursu izmantošanas uzdevums ir ne tikai palielināt Latvijas enerģētikas pašnodrošinājumu un līdz ar to palielināt neatkarību no importētiem energoresursiem, bet arī dot ievērojamu ieguldījumu siltumnīcefekta gāzu emisiju samazināšanā. Biomasa ir būtisks atjaunojamo enerģijas avotu resurss, tāpēc nepieciešami pētījumi par biomasas cietā kurināmā ražošanas procesu.*

Kompaktējot dažādu frakciju niedres (< 0.5; 1 – 2; 3 – 4; 5 – 6; 7 – 8; 12 – 13; 22 – 23; 32 – 33 mm), noskaidrots brikešu blīvums, presēšanas specifiskā enerģija un spēka – pārvietojuma līkņu raksturs. Eiropas Savienības valstu standarti nosaka to, ka brikešu, kas tiek izmantotas kā cietais kurināmais, nepieciešamais blīvums ir ~1 g cm^{-3}. Eksperimentāli noteiktā brikešu blīvuma mazākā vērtība (0.87 g cm^{-3}) ir briketēm ar frakciju lielumu 12 – 13 mm, bet lielākās brikešu blīvuma vērtības (1.03 – 1.04 g cm^{-3}) ir briketēm ar frakciju lielumiem < 0.5 un 32 – 33 mm. Aprēķinot specifisko kompaktēšanas enerģiju, maksimālā vērtība ir ~172 kJ kg^{-1}, bet minimālā – 53 kJ kg^{-1}. Kompaktēšanas eksperimenti veikti slēgtā matricā, kuras diametrs ir 35 mm, līdz 212 MPa spiedienam. Spēka – pārvietojuma līknes nepieciešamas kompaktēšanas mehānismu projektēšanai.